Patent Application of

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for

TITLE: FIRE EXTINGUISHING SYSTEM FOR LARGE STRUCTURES

CROSS-REFERENCE TO RELATED APPLICATIONS Not Applicable

FEDERALLY SPONSORED RESEARCH Not Applicable

SEQUENCE LISTING OR PROGRAM Not Applicable

BACKGROUND OF THE INVENTION -- FIELD OF ENDEAVOR

The present invention generally relates to systems and methods for fighting fires in a protected space, and more particularly, to fighting fires in large structures, buildings, ships, and the like.

BACKGROUND OF THE INVENTION

Fire detection and extinguishing systems for office buildings, warehouses, sky-scrapers, and so forth typically involve fire doors, thermally activated sprinkler heads, extinguishant, and a central control panel to monitor the overall system. For instance, U.S. Pat. No. 4,091,874 to Monma (May 1978) discloses a building-wide system consisting of detectors, warning signals, actuated fire doors, extinguishers, a suction system, a control panel, and timers, to automatically control doors and extinguishers. U.S. Pat. No. 5,486,811 to Wehrle, et. al. provides early detection and extinguishment of fires using, among other components, carbon monoxide sensors,

flame detectors, and a central controller that transforms sensor data into a "profile" to correlate that data with known data.

Such inventions strive to optimize fire detection and prevention, but they all exhibit several shortfalls. No autonomous and damage-tolerant methods have been proposed for delivering very large quantities of fire retardant, via a building-wide system of selectably interconnected reservoirs having redundant flow paths, to provide a volume of retardant that can extinguish major fires within a building. On the contrary, fire fighting systems for skyscrapers and office buildings typically strive to minimize redundancy; they are generally incapable of extinguishing very intense fires; and they are not able to autonomously re-route retardant throughout a building or structure to the fire location in reaction to damages within the fire fighting system itself.

For example, some fire detection and extinguishing systems of the prior art utilize the building-wide common water supply for the source of fire retardant. When piping is substantially damaged in such a system, retardant is wasted by leaking at the damage points; and pressure is reduced, thus reducing the volume of water flow where it is needed. As another example, other systems of the prior art utilize discrete extinguishing subsystems, each consisting of its own reservoir and pipes supplying retardant to sprinkler heads. When a fire is detected, and sprinkler heads activate, and then the reservoir consequentially empties, there are no automatic and damage-tolerant means to supply more retardant to the empty reservoir from other full reservoirs.

Accordingly, the new invention being disclosed is an enhancement and advantageous over the prior art, as it detects and controls intense fire in large buildings or structures such as office buildings, sky-scrapers, cruise ships, aircraft carriers, and the like, using a method of retardant distribution and sharing that reacts automatically, not just to fires and the need for a supply of fire retardant, but it also responds automatically to damage to the fire extinguishing invention itself.

BACKGROUND OF THE INVENTION -- OBJECTS AND ADVANTAGES

The prime purpose of this invention is to extinguish intense fires within a large structure; and more specifically, to extinguish large fires within the constraints of a degraded fire suppression system, for instance being damaged by earthquake, explosions, and so forth. Several objects and advantages of the present invention over prior art are:

(a) to selectably and automatically distribute and share retardant, supplying retardant via multiple flow paths where needed;

(b) to sense and react to system statuses, such as fire detectors, reservoir levels, and system damage;

(c) to automatically and selectably seal and isolate retardant reservoirs as appropriate;

(d) to spatially separate reservoirs and retardant piping paths so that localized damage to any structure affects the fewest number of reservoirs and piping;

(e) to connect sensors to controllers in overlapping topologies; and

(f) in certain embodiments, to use gravity to induce retardant sharing.

As will be shown, the resulting fire suppression invention is thus able:

- to automatically supply very large amounts of retardant to fire areas, by virtue of a plurality of relatively small, interconnected reservoirs throughout the structure to be protected;
- to react automatically to damage and subsystem malfunctions, by virtue of damage sensors and the selectable and automatic sealing and isolation of reservoirs, and due to the several subsystem redundancies and redundant flow paths;
- to suppress fires, automatically or manually, by virtue of fire sensors, reservoir level sensors, retardant valves, and electronic controllers.

Although some descriptions herein contain certain specifics, these should not be construed as limiting the scope of the invention, but as merely providing illustrations of some of the presently preferred embodiments of this invention. For example, the figures depict fire retardant as being a liquid, shared and delivered to the fire primarily by gravity power. Such a configuration was chosen to simplify drawings and explanations. Any suitable retardant type, and any pumping, pressure, or delivery system may be employed. As another example, conducting wires are described for sensors and control signals, with bi-level voltages. However, modulated, multiplexed, networked, fiber-optic, or wireless communication could be used where

appropriate. Thus the scope of the invention should be determined by the claims and their legal equivalents, rather than by the examples given.

SUMMARY OF THE INVENTION

In accordance with the present invention, automatic fire detection, and extinguishment thereof, is provided to large structures or protected spaces, with the ability to deliver extensive quantities of fire retardant to the fire location, while automatically compensating for damage to the fire extinguishing system itself. A network, comprising retardant reservoirs, piping, valves, sensors, and controllers, causes automatic extinguishment of fires; shares fire retardant between various locations automatically; and remains substantially tolerant to system damage.

Such automatic retardant sharing, and damage tolerance, are achieved by sensors, system redundancies, selective isolation of subsystems of retardant, various spatial separations, and other design considerations.

Sensors used in the invention include sensors used in standard prior art fire extinguishing systems, such as temperature detectors, CO detectors, and the like, plus various other system status sensors, including reservoir level sensors and piping continuity sensors. These sensors interoperate by way of various electronic controllers and monitors.

The present invention relies on environmental sensing, redundancies, retardant flow and confluency control, autonomous

subsystem self-monitoring, spatial separations, and controllers, to achieve the stated goals.

Thus, when fire(s) within the structure occur, this invention detects such fires and supplies fire retardant thereto, as in prior art. Yet moreover, this invention also compensates for damage to the fire extinguishing system itself; and, it allows (by way of retardant sharing), as needed, very large amounts of retardant to be delivered to the fire areas through a network of flow paths, thus allowing substantially intense or large fires to be extinguished.

In some embodiments there is substantial use of gravity to cause fire retardant flow, and in such embodiments, the majority of retardant is located preferably in reservoirs at relatively higher vertical positions within the structure.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

To illustrate this fire extinguishing invention, a preferred embodiment will be described herein with reference to the accompanying drawings.

Fig 1 shows the preferred embodiment, a diagram of part of the invention installed within a large building.

Fig 2 shows retardant refill interconnections for the case where water is used as a retardant in accordance with the present invention.

Fig 3A shows the interconnection of one level (floor) in accordance with the present invention.

Fig 3B shows the autonomous controlling of retardant flow to a sprinkler head in accordance with the present invention.

Fig 3C shows a block diagram of certain subsystems of the invention, illustrating, for the preferred embodiment of the invention, components and interconnections used to sense system status and possible piping damage, and to automatically compensate therefor in accordance with the present invention.

Fig 4A shows a schematic circuit diagram for implementing automatic fire retardant sharing in accordance with the present invention.

Fig 4B illustrates the manner that sensor data is collected from a substantial number of floors below each unit that controls retardant sharing to those floors in accordance with the present invention.

Fig 5 is a circuit schematic showing master control panel interconnections in accordance with the present invention.

DRAWINGS -- Reference Numerals

10 retardant reservoir
20 fire retardant
25 retardant flow direction
30 vertical share piping
31 horizontal share piping
32 sprinkler piping
40 vertical sharing valve
41 horizontal sharing valve
42 breach valve
43 sprinkler cutoff valve
50 extinguisher valve
60 sprinkler head
70 reservoir sensor
72 reservoir annunciator
100 reservoir empty signal
101 reservoir empty' signal
102 reservoir empty annunciator
105 reservoir empty lamp
110 continuity wire
112 discontinuity annunciator
115 discontinuity lamp
120 retardant share inhibitor
130 share request signal
135 share lamp
140 share control switch
141 master share auto select
142 master share open select
143 master share close select
144 inverted master share close
200 master controller
320 CO detect signal
322 CO annunciator
325 CO lamp
329 CO detector
330 over-temperature signal
332 over-temperature annunciator
335 over-temperature lamp
338 ground reference
339 over-temperature sensor
340 fire detect signal
341 fire detect' signal
345 fire lamp
349 fire analyzer
400 building damage monitor
405 building damage lamp
410 building damage continuity signal
412 building damage annunciator
415 building damage lamp
500 refill piping
510 water system
520 refill valve
AG1 AND gate
AG2 AND gate
AG3 AND gate
IN1 inverter
OG1 OR gate

DETAILED DESCRIPTION - PREFERRED EMBODIMENT

Referring now to the drawings, and more particularly to **Fig 1**, there is shown a preferred embodiment of the invention for use in a skyscraper or large vertical structure, to illustrate retardant flow control and fluid interconnections therewithin. Shown is a plurality of retardant reservoirs **10**, each of which contains a fire retardant **20**, positioned at predetermined strategic vertical and horizontal intervals within the structure that is to be protected from fire by the invention.

The type of fire retardant used with this system is largely inconsequential, but the figures assume that it is water. The vertical and horizontal intervals for retardant reservoirs should be chosen according to the specific embodiment of the invention, and according to various structural and environmental considerations. The descriptions and figures herein describe an embodiment wherein several retardant reservoirs are placed on each floor of the structure.

Regarding the selected fire retardant, any appropriate single retardant, or combination of retardants, may be used. This includes, but is not limited to: water, dry chemicals, foams, inert gases, powdered aerosols, and halons. Combinations of retardants are advantageous when, for instance, one section of a protected space contains inflammable materials of a substantially different composition than another. As another example, humans may occupy one section (and thus non-toxic retardants are prescribed), and another section has no human occupants. When retardant combinations are used, then clearly separate, isolated piping and reservoir networks may be necessary (depending upon

the nature of the retardant combinations). Such separate networks may nevertheless be installed to protect the same protected space, and may share subcomponents such as sensors and controllers.

The retardant reservoirs are interconnected by a vertical share piping **30**, and by a horizontal share piping **31**. Such piping and reservoirs are redundantly interconnected via paths that are significantly spatially separated. This forms a web-like network of piping that is selectably placed in fluid communication between any desired nodes, via electrically controlled valves. This network of piping is arranged with multiple, or "topologically parallel" flow paths, such paths being substantially separated from one another in space.

"Retardant sharing," or flow of retardant between reservoirs or nodes, can be inhibited or allowed as necessary by a plurality of vertical sharing valves **40**, and a plurality of horizontal sharing valves **41.** These sharing valves are normally closed; but when opened, they provide fluid communication between reservoirs or nodes. This effectively supplements the volume of retardant suppliable to any lower location, and thus provides substantial retardant where needed.

The default state during operation maintains sharing valves in their closed position, resulting in a "safemode" system: fluid communication between retardant reservoirs is consequently inhibited. Thus, any potentially damaged pipes or reservoirs are not in fluid communication in such state.

A path, or paths, for retardant flow through the plurality of interconnected piping can be selected by opening certain valves, thus allowing sharing of retardant. As will be seen, in the case where there are sections of damaged piping or damaged reservoirs, the present invention automatically routes retardant through undamaged piping when needed, while sealing off flow to damaged areas. Moreover, re-routing and sharing of retardant can also be manually controlled, as will be shown in paragraphs that follow.

With the exception of manually operated valves described in sections to follow, the type of valves used in the preferred embodiment are those typical of prior art that are electrically actuated, moving (fully closing or opening) when a signal or voltage is applied (thus, for instance, actuating a solenoid), and which rest (for example, springably) in a "default state" when voltage is not applied. Unless otherwise noted, all electrically actuated valves used in the invention are "normally closed" to keep reservoirs and nodes independent and safe, in the case of ad hoc damage to other sections. As is otherwise noted herein, certain other electrically actuated valves are of the "normally open" type.

By way of clarification, to provide fluid communication between any two reservoirs or nodes for retardant sharing, an embodiment could conceivably incorporate a single horizontal sharing valve **41**, for instance at the middle of a horizontal share piping **31**. But in the preferred embodiment, the sharing valves **40** & **41** are configured each as valve pairs, placed at opposite ends of the share piping. This is a very important design consideration: with dual valves at opposite ends of piping, if a share piping is damaged between the valve pairs, the

retardant is not emitted, and thus retardant is not lost through the piping leak point. So, in this preferred embodiment, the valve controller must open both of the sharing valves to cause retardant flow between any two connected reservoirs. Further, as will be shown, similar distally opposed valves work in concert with devices that will be introduced such as continuity sensors, to automatically react to piping breaches, and to enable re-routing of retardant flow, as needed, through undamaged piping.

As in typical extinguishers or sprinkler systems, an extinguisher valve **50** actuates when needed, to cause retardant flow from the reservoirs, through a sprinkler piping **32**, to a sprinkler head **60**, to extinguish the fire. A sprinkler cut off valve **43** shown in the figure is explained in sections and drawings that follow. It is possible to use standard automatic sprinklers of prior art as the sprinkler head **60**, for example containing therewithin the extinguisher valve **50** (which may be the fusible obturator type of prior art, acting as the valve). In such case, flow detectors that are typical in such prior art, and used with fusible sprinkler valves, may be applied as appropriate within the invention, to supply the desired sensor data to various described subcomponents, indicating that a sprinkler valve has been opened (for instance, by flames).

Automatic retardant sharing between different nodes or sections within the structure involves primarily the sharing valves **40** and **41**. Automatic fire extinguishing -- that is, delivery of retardant to a sprinkler -- primarily involves extinguisher valve **50.** Control over sharing valves may be automatic, via the sensors and controllers local to the valves, or manual, via a master controller **200**; in any preferred

embodiment, sharing involves a combination thereof. Figures that follow clarify, and provide examples of such control via the master controller **200,** automatic sensors, and other controlling subsystems.

A plurality of breach valves **42** shown in the figure are electrically actuated, and are normally OPEN.

Breach valves are closed automatically when an associated damage sensor indicates there is physical damage to the piping. In the preferred embodiment, the damage sensor for piping consists of a continuity wire **110** (not shown in **Fig 1**), such wire being run closely from end to end along and proximate to share piping **30** and **31**, and similarly to sprinkler piping **32**. Breaking, opening, or grounding of such continuity wire is presumed to be caused by unwanted damage, fire, explosion, and so forth; and thus, integrity of the proximate piping becomes suspect. As such, when any of the continuity wires becomes discontinuous, an "open" (or "floating"), or possibly ground level voltage is sent to the actuating circuitry of breach valve **42,** which closes the valve. A non-zero, rather than a ground voltage, is applied at the distal end of all continuity lines, so that any short to ground is detected and interpreted as a breach.

In other embodiments, a "damage sensor" may be any other sensor indicative of physical damage to a component of the system, especially damage to the retardant network, including piping, valves, and reservoirs. Such damage sensors include, but are not limited to, one or more of: flow sensors, pressure sensors, temperature sensors, electrical sensors, cameras, and moisture sensors.

Thus far, piping, reservoir flow, and related valves have been shown, but electrical interconnections and various controllers have not been in the drawings. The interconnections of various controllers and sensors are shown in figures to follow.

If water is used as fire retardant, then initial reservoir fillings, and refilling, are preferably accomplished using the public water system. **Fig 2** shows refill piping **500**, which may be placed in fluid communication with a standard (e.g. public) water system **510** for one of the retardant reservoirs **10** when a refill valve **520** is in the open position. The refill valve **520** is preferably a manually operated mechanical shut-off valve, normally kept closed to keep reservoirs in the safe mode. Every water reservoir in the system is connected to the standard water system through sections of refill piping. In this preferred embodiment, the refilling system is kept simple and manual.

Regardless of the type of retardant used, there is a need to refill reservoirs from time to time, for instance due to use of retardant, or minor leaks. A reservoir empty sensor **70** detects such need by raising a reservoir empty signal **100** and thus, among other things, activating a reservoir empty annunciator **102** to alert the user (or building superintendent), and sending a signal to the master controller **200**.

To clarify intended uses of system components, the reservoir empty sensor **70** and the empty annunciator **102** work in duality for one purpose to notify the need for maintenance (manual) refilling. However, the reservoir empty sensor also works with

other sensors and control signals to provide data that is used for automatic retardant sharing, as will be further explained.

The plurality of reservoir empty sensors are configured such that there is substantial hysteresis in their status reporting. Moreover, they signal "empty" (or better stated, "refilling desired") status when the retardant level has not yet been depleted to the mesial level. For instance, to signal "empty" status when the reservoir is 75% full, and by way of hysteresis, to terminate the "empty" status signal when the reservoir is 90% full.

Fig 3A provides an illustration clarifying the interconnection of one typical floor (vertical level) by showing a bird's eye view of one floor of reservoirs, piping, and valves. For simplicity, four retardant reservoirs **10** are shown, and horizontal share piping **31** therebetween. Share piping to other reservoirs on that floor are omitted from the drawing. For any embodiment, the number of reservoirs and their positioning should be considered with scrutiny by building architects and fire control experts.

Pairs of reservoirs are shown in the figure connected via horizontal share piping **31**, and they are either isolated or placed in fluid communication depending upon the position of (pairs of) horizontal sharing valves **41** and breach valves **42**. Flow of retardant to sprinkler head **60,** shown in the figure by retardant flow direction arrow **25**, is provided by horizontal sprinkler piping **32**, and allowed or prohibited by the breach valve **42**, and (manually operated) sprinkler cutoff valve **43**. Standard automatic sprinklers of prior art may be used, and thus

the extinguisher valve would be located within the sprinkler head. The drawing shows a plurality of continuity wires **110**. Interconnections to valves and controllers are detailed in sections that follow.

Turning now to **Fig 3B**, there is shown therein autonomous retardant flow control from the reservoir **10** to the sprinkler head **60**. Retardant must first pass through the sprinkler shut-off valve **43**, which is of the manual type valve. During operable deployment, all sprinkler shut-off valves are placed in their open position. In the cases of system tests, false alarms, repair procedures, and so forth, they may be closed. Each breach valve **42**, and each sprinkler shut-off valve **43**, is located proximate to its counterpart reservoir.

In this figure, an assembly of the breach valve **42** is shown schematically as a "subsystem" of sorts, comprising therewithin several subcomponents, and some detail regarding control circuitry. Shown therein is a typical electrically-operated valve, incorporating a standard buffer/inverter and pull-down resistor configuration. In this configuration, a simple (DC low-voltage) data signal line is the input to the valve control circuitry, which data signal line is amplified and inverted such that a plus voltage on the low power data signal line (that is, the continuity wire **110**) results in a signal to the valve control circuits that results in the default valve position. Specifically, a plus voltage on the continuity wire **110** will result in a ground voltage to the valve actuator (a solenoid), thus leaving the valve springably in its default (in this case, OPEN) position. Because of the pull-down resistor, a break in the continuity wire **110** causes a plus voltage at the valve, and

thus results in valve actuation to the opposite (CLOSED) position, sealing the reservoir from the sprinkler piping **32**.

Fig 3B thus illustrates retardant flow control from reservoirs to sprinkler heads. The data signal (a DC voltage from the "+" source shown in the drawing) from the distal end of the continuity wire **110** is used to inhibit retardant flow when the sprinkler piping **32** has been damaged, and also causes discontinuity annunciator **112** to sound when there is a break. The "+" voltage source must have impedance or protection such that shorts of continuity wire **110** to ground are tolerated. Thus, the continuity wire acts, in this case, not specifically to control sharing of retardant, but to prevent leakage at any node within the network of reservoirs when there is damage to sprinkler piping, which reservoirs are possibly in fluid communication when in a "sharing" mode. Other figures illustrate how the plurality of continuity wires is also used to control retardant sharing between other nodes.

An over-temperature sensor **339**, and a CO detector **329**, act in harmony as fire detectors. In the interest of simplicity in this discussion and drawings, only these two types of fire detection sensors are shown. Depending upon the nature of the structure to be protected and combustibles therein, and along with various cost and complexity factors, additional fire detectors should be employed, such as smoke detectors, IR sensors, and the like. The term "fire detector" as used herein thus refers to any device capable of detecting the presence of a fire, or signs of a fire, such as heat, smoke, carbon monoxide, flames, et cetera.

An over-temperature signal **330** from the over-temperature sensor, and a CO detect signal **320** from the CO detector, are fed as input signals to a fire analyzer **349**. (In the example shown, the fire analyzer may comprise simply a logical OR of the two sensor signals. But in other embodiments, several sensor signals may be fed into fire analyzer, requiring a more complex fire analyzer.) The output from the fire analyzer is a fire detect signal **340** that acts as input to the extinguisher valve **50**; to the master controller **200**; and to a retardant share inhibitor **120**. The use of the retardant share inhibitor will be explained in sections and drawings that follow.

Thus, if the sprinkler piping **32** is damaged, the present fire control invention automatically inhibits otherwise wasted retardant flow, using the breach valves and related sensors and controls. Within a network of retardant piping, each extinguisher valve **50** has a dedicated continuity wire **110**, being run proximate to the sprinkler piping that supplies retardant to the extinguisher valve, and connected as shown in the figure. By contrast, not every extinguisher valve **50**, nor every sharing valve (**40** and **41**), requires the retardant share inhibitor **120** to be dedicated thereto. As will be shown in sections and drawings that follow, certain sensor data are fed in an imbricate topology from many locations within the structure to each retardant share inhibitor that controls sharing for a predetermined number of associated valves.

The CO detector **329** also activates a CO annunciator **322** disposed locally to the CO detector, when CO is detected. And the over-temperature sensor **339** activates an over-temperature

annunciator **332** disposed locally to the over-temperature sensor, when an over-temperature condition is detected.

Fire detection by "profiling" is a prior art method that wherein various sensor data are fed into a profile evaluator, which compares the input data to known profiles stored in memory. The sensor data profile evaluator determines if there have been changes to certain sensor conditions or trends that would indicate, based on known (stored) sensor data, the early stages of a fire. Profile evaluators typically use a combination of various sensor types, such as CO detectors, flame detectors, temperature sensors, and humidity sensors. Fire detection using this method can result in enhanced sensitivity and selectivity (fewer false alarms). The present invention is adaptable to such profiling methods. As will be appreciated by those skilled in the art, such profiling is easily integrated with the aforementioned fire detector subsystem.

The primary purpose of **Fig 3B** is to introduce the fundamental principles for retardant flow control to sprinkler heads, and the directly related subsystems. Additional signal interconnections not shown in this drawing are described in the sections to follow. The preferred embodiment thus comprises the essence of all the features, subcomponents, interconnections, and topologies that are presented in the collection of the Preferred Embodiment figures.

Referring now to **Fig 3C**, shown therein are two vertically opposed reservoirs **10** on adjacent floors, and interconnection of sensors and electronic signals to monitor fire, reservoir levels, and to detect and react to system damage. In the configuration

shown, breaches to the vertical share piping **30** are tolerated between the two reservoirs and vertical sharing valves **40**, because the continuity wire **110**, which is run proximate to the share piping, detects such damage and causes the breach valve **42** to close. This placement of the continuity wire is chosen so that damage to the share piping also results in damage to (or grounding of) its counterpart piping continuity wire **110**.

The details of the signal communications are largely not critical to operation of the invention, but it is preferable that the master controller **200** is able to manually override some automatic valve control, and that sensor information be provided to the master controller to be used for panel status lights and annunciators. The figures show all signals as hard-wired to master controllers in the preferred embodiment. Such a configuration is not mandatory and should be chosen as each situation dictates. Alternate configurations (for instance transmitting sensor signals to the master controller via radio waves) have certain advantages. The master controller is discussed in more detail in sections and drawings that follow.

The signaling means discussed and illustrated in the preferred embodiment conveys data or information from one component to another through electrical wires, supplying a "True" or "False" signal state (positive or ground voltage), to: indicate a sensor's status; or to control a component; or both. Thus, the signaling means is a method of control, or a method of communicating data or information.

In other embodiments of the present invention, the physical communicative elements for such signaling may be chosen from among any appropriate configuration. This is typically called the "physical layer" and the "datalink layer." Similarly, any number of transforms, modulators, encoding schemes, or protocols may be chosen to implement a higher level of a signaling means, when desired. This generally relates to what is called the "network layer" or "transport layer." Such terminology is largely idiomatic of contemporary electronic communications protocols. Nevertheless the terminology serves to convey the generic meaning that any sort of signaling means consists of something physical (for instance, a wire, or a hydraulic line), and possibly a "higher level" of modulation or language (for instance, frequency modulation, or a protocol such as TCP/IP).

Such elements for the physical or datalink layers include, for instance: wires; optics; radio waves; hydraulics; gears; linkages; and combinations thereof. Appropriate network or transport layer transforms for electrical signaling include, for instance: bi-level voltages; analog voltages; analog modulation; digital encoding; multiplexing; packetizing; and combinations thereof.

An appropriate signaling implementation for the present invention is a combination of: electrical wiring with bi-level voltages; an Ethernet LAN; manual switches; electronic gates; and wireless Ethernet. Typically at the receiving end of such signaling are the subcomponents such as: valve circuitry and related solenoids; status indicator lamps; warning annunciators; video screens; and controllers. When constructing any embodiment of the present invention, many factors - such as environment, reliability, feasibility, and cost - come into play. As such,

the choice of signaling means, as well as other design choices, should be scrutinized.

The figure shows how the retardant share inhibitor **120** for each floor can be placed in manual or automatic mode via three control signals: a master share auto select **141**, a master share open select **142**, and a master share close select **143**. The retardant share inhibitor processes those control signals, as well as sensor signals, such that in the automatic mode, sharing is not allowed unless a fire is detected and piping integrity is apparent. In the manual mode, sharing valves (**40** or **41**) controlled by the retardant share inhibitor **120** may be manually opened or closed by the operator at the master controller **200**.

Also shown in the drawing are a plurality of fire analyzers **349**. A TRUE signal from any fire analyzer causes a TRUE input signal to retardant share inhibitor **120**. This is illustrated in the figure by an OR gate that collects the plurality of the fire detect signals **340**, forming one signal sent to the retardant share inhibitor (and master controller **200**), a fire detect' signal **341**. In a typical embodiment, including the preferred embodiment, each floor has a plurality of fire analyzers. Moreover, as will be shown in figures to follow, each retardant share inhibitor is similarly provided sensor data from a collection of floors below.

When the retardant share inhibitor **120** asserts TRUE on a share request signal **130**, it the opens the sharing valve(s) **40**, and also sends that share request signal to the master controller **200** (for status display purposes). Retardant will thus flow, and

will be shared to the next node (in this figure, "RESERVOIR B"), if the breach valve **42** is also open, as controlled by the continuity wire **110**.

In this preferred embodiment, the continuity wire **110** is electrically connected at its distal end to a voltage source (shown by the "+" in the drawing), to supply a non-ground voltage when continuity is intact (when the vertical share piping **30**, which is in close proximity, is apparently functional).

Whereas **Fig 3C** shows circuit interconnections and piping for sharing between reservoirs that are vertically opposed, and thus shows "vertical retardant sharing," similar interconnections are used for horizontal retardant sharing. Moreover, for horizontal piping, and for certain vertical piping (such as in a pressurized system), the sharing valves (**40** or **41**) are configured as distal pairs, placed at opposite ends of the share piping, each valve in such pair being simultaneously controlled by the share request signal **130**.

For the sake of introducing certain components and their interconnections, this **Fig 3C** is a simplified version of a section of the invention. In both the vertical and horizontal cases, actual interconnection of signals from sensors connected to any retardant share inhibitor **120** must be multiply imbricate, connecting a predetermined number of sensors from adjacent floors (or adjacent horizontal locations) to vertically superior retardant share inhibitors. Such overlapping topology is explained in more detail in paragraphs that follow.

Two comparative terms, "vertically superior," and "vertically subordinate" will be used herein to refer to the flow possibilities for retardant. In a simple unpressurized (or gravity-powered) system, flow is basically either horizontal, or downward, and hence for a reservoir on a particular floor, all piping below that floor is considered vertically subordinate. Horizontal flow is similar in nature (due to inherent pressure in reservoirs caused by gravity), and hence all horizontal share piping connected to a reservoir is also referred to as vertically subordinate. The counterpart term "vertically superior" refers to the opposite state; for instance, a reservoir on the 20th floor is vertically superior to piping in fluid communication with it on the 19th floor and all floors below.

In alternate embodiments using a pressurized system, retardant flow may be upward. As such, depending upon the pressure, the nature of the retardant, and the magnitude of the retardant confluency network, the terms "vertically superior" and "vertically subordinate" may have no meaning, or may be differently defined. Thus, retardant flow characteristics in any such alternate embodiment must be taken into consideration.

Fig 4A shows a schematic circuit diagram of the sensor signals and control signals used by the retardant share inhibitor **120**; processing thereof within the share inhibitor; and the control signal generated therefrom. A plurality of such retardant share inhibitors is employed in this invention (typically one per floor), to control the plurality of associated vertical sharing valves **40** and the plurality of horizontal sharing valves **41**. The circuit of **Fig 4A**, when placed in auto-mode by the master controller **200**, asserts a TRUE (plus voltage) on the share

request signal **130**, to open the plurality of sharing valves (normally, all horizontal sharing valves on that floor, and all vertical sharing valves connected to the floor below) when sharing is desirable. Sharing is deemed "desirable" when there are both a presence of a fire indication, and a partially empty reservoir, at a subordinate floor. It asserts a FALSE (ground voltage) otherwise, keeping sharing valves closed. However, the ability to intervene autonomous operation is desirable in such a system, and therefore, this invention provides manual override by the master controller, to allow the user (for example, building superintendent) to open or close sharing valves manually. Regardless of autonomous or manual mode, the continuity wire and breach valve prohibit retardant sharing through flow paths where damage is detected, as described earlier and shown in previous figures.

The controllers and valves thus react to the various sensors, to intelligently open sharing valves when needed and when piping is undamaged, and to seal and isolate retardant flow when sharing is not needed or when piping integrity is breached.

As shown in **Fig 4A,** the plurality of fire detect signals **340-A** through **340-F**, each of which comes from separate fire analyzers (not shown in this figure) are combined (logically ORed) to provide a fire detect' signal **341**, a first input into the circuitry of the retardant share inhibitor **120**. For simplicity, only six fire detect signals are shown in this figure; but the number of fire analyzers on each floor, and the depth of inter-floor imbrication, may be chosen differently. The fire detect signals serve to close sharing valves when there is no evidence of fire. A plurality of reservoir empty signals **100-A** through

100-F are similarly combined to provide a reservoir empty' signal **101** to indicate the need for retardant sharing. An AND gate **AG1** logically ANDs the fire detect' signal **341** with the reservoir empty' signal **101.** The resultant signal is input to an AND gate **AG2** along with the master share auto select **141.** The output signal from the AND gate **AG2** is input to an OR gate **OG1**, along with the master share open select **142**. The output from the OR gate **OG1** serves then as input to an AND gate **AG3** along with an inverted master share close **144**, which is obtained by passing the master share close select **143** through an inverter **IN1**. The output of the AND gate **AG3** forms the share request signal **130**, which is fed directly to the master controller **200,** and to the plurality of sharing valves under control (**40** and **41**), such sharing valves typically comprising all horizontal sharing valves for that floor, and all vertical sharing valves providing flow to the next floor below.

The present invention thus inhibits retardant flow that would be undesirable, unneeded, or wasted, in the case that, for instance: piping is damaged (signaled by the continuity wire); or if there is no apparent fire (signaled by the fire analyzer); or, if there are no retardant-receiving reservoirs that need replenishing (signaled by reservoir sensors).

To simplify figures and descriptions, a simple form of data signal communication (one wire) has been shown. In most cases, is preferable to use a more robust interconnection scheme, for example running both the signal wire and a ground reference wire.

Referring now to **Fig 4B**, the multiply imbricate sensor interconnections are shown therein. Multiply imbricate sensor

interconnections represent an important design consideration for this invention. Yet, in a structure of the type of a skyscraper or large ship, for example, there are so many sections and floors, that 100% building-wide connectivity of sensors and controllers is typically not desirable. The ideal situation is to implement a sensing topology that is imbricate between many floors, and cascaded such that, for any given vertically superior floor, fire sensing data and reservoir empty data are provided from a predetermined number of vertically subordinate floors. That is to say that, in the context of the present invention, for each floor, there are multiple sensor inputs to the retardant share inhibitor **120** for that floor, such sensor inputs being "ganged" (logically ORed) from a large number of floors or sections that are vertically subordinate to that retardant share inhibitor **120**.

This sensor system thus provides retardant sharing between many floors and nodes when sharing is desirable and when the share piping is functional; but it inhibits sharing when sharing is not needed, inhibiting flow through any pipes that are breached. The need for retardant at fire(s) below any particular share inhibitor **120** will cause multiple selected sharing valves to open. Web-like fluid interconnection results, causing flow through undamaged piping to the source of the fire(s).

Thus the drawing **Fig 4B** shows just such an overlapping and imbricate sensor arrangement. The vertical positions of the sensors shown on the drawing generally correspond to vertical positions of actual sensors within the structure, the top of the page representing higher floors. For the sake of simplifying this drawing, inter-floor imbrication is shown as three floors

deep. However, in a preferred embodiment, optimal imbrication depth should be chosen depending upon the structure's architecture, type of fire threat, and cost-benefit analyses. A typical inter-floor imbrication depth is 10 to 30 floors.

A limited, rather than "pan-building" imbrication depth, constrains the extent of automatic retardant sharing within the fire extinguishing invention, which is often desirable due to pressure constraints. For instance, depending upon the retardant and fire-suppression system in question, too many pipes placed in fluid communication may cause rupture due to combined weight (and thus pressure) of retardant.

As shown in the drawing, the plurality of reservoir empty signals **100**, supplied from a predetermined number of vertically subordinate floors, are combined (logically ORed), the output therefrom being the reservoir empty' signal **101**. Similarly, the fire detect signals **340** are supplied from subordinate floors and are combined to form the fire detect' signal **341.** Those combined signals, **101** and **341**, are fed into the retardant share inhibitor **120** for that floor, and to the master controller **200**. Each fire detect signal **340** is also fed into the extinguisher valve **50** that is assigned to protect the area of the fire detection sensor (not shown in this figure, but shown in **Fig 3B**).

This drawing (**Fig 4B**) is intended primarily to show the sensor interconnections and imbrication thereof, in the case of vertical retardant sharing control. Similar control and interconnection of horizontal sharing are also incorporated for structures of substantial horizontal extent, such as large ships or underground mines; and sensor imbrication should be employed as applicable.

Thus, sensor interconnections of a similar arrangement along the horizontal plane are also used for horizontal sharing, the imbrication depth and topology being chosen depending upon circumstances. In the typical embodiment, this forms a three-dimensional sensor plexus with multiple overlapping inputs to each of the retardant share inhibitors **120**. Each retardant share inhibitor in turn controls both a plurality of horizontal sharing valves for the floor where it resides, and the plurality of vertical sharing valves to the next floor below.

Thus, reservoirs and piping, reticulated throughout the structure with multiple possible flow paths and with substantial spatial separation, form a fluid network to provide the infrastructure for retardant sharing and flow to sprinkler heads. The imbricated interconnection of sensor data sent to valve controllers, from adjacent locations on the same floor, and from many floors below each retardant share inhibitor, automatically causes selected sections of the piping plexus to be placed in fluid communication when needed. Moreover, each segment of piping is self-isolating when damaged, due to the continuity wire **110** and the corresponding valves.

Referring now to **Fig 5**, there is shown therein a circuit schematic diagram of interconnections of sensor lamps and valve control switches for the master controller **200**. Sensor data is shown in this figure displayed for one floor. The master controller is comprised of a plurality of such set of such status indicator lamps and switches, one for each floor.

As with circuits previously described, bi-level voltages (plus or ground) are indicated, and buffers and pull-down or pull-up

resistors are used as appropriate. Referring to the figure, there is a plurality of sensor lamps for the floor, and a share control switch for each floor. Each floor's sensor lamp illuminates based on sensor inputs as follows:

- a fire lamp **345** illuminates when the fire detect' signal **341** is raised for that floor;
- a reservoir empty lamp **105** illuminates when the reservoir empty' signal **101** is raised for that floor;
- a discontinuity lamp **115** illuminates when the continuity wire **110** is breached for that floor;
- a share lamp **135** illuminates when the share request signal **130** is raised for that floor.

In any preferred embodiment, when any sensor lamp illuminates for any floor, an annunciator is also activated (not shown in the figure) to alert the user audibly.

Referring still to **Fig 5**, a share control switch **140** allows the user to control the mode of operation for retardant sharing for any particular floor or segment of the piping network. In the figures, segmentation is shown on a floor-by-floor basis, but other configurations are valid.

Selecting "AUTO" on the share control switch for a particular floor asserts TRUE on the master share auto select **141** transmitted to that floor, and FALSE on the master share open select **142** and the master share close select **143**. This setting places the retardant share inhibitor for that floor in automatic mode. Selecting "CLOSE" for a particular floor asserts TRUE on the master share close select **143**, and FALSE on the master share auto select **141** and the master share open select **142**. This

setting overrides the retardant share inhibitor for that floor, closing all related sharing valves. Selecting "OPEN" for a particular floor asserts TRUE on the master share open select **142**, and FALSE on the master share auto select **141** and the master share close select **143**. This setting overrides the retardant share inhibitor for that floor, opening all related sharing valves.

Operation

The manner of using this fire extinguishing invention is similar to fire extinguishing systems of prior art. First, the retardant reservoirs must be filled. In the case where water is used, this involves placing refill valves **520** in the open position until reservoirs are adequately filled. The reservoir empty signals, and annunciators, aid the user in this process. Depending upon the embodiment of the invention, manual valves such as sprinkler cutoff valves **43** may be best left closed during refilling operations.

The refill valves should then be placed in the closed position. An appropriate settling time should be allowed to elapse. Thereafter, any indication of empty reservoirs, signaled on the master controller by reservoir empty lamps, or by reservoir annunciators local to reservoirs, probably indicates leaking that should be repaired.

The share control switches **140** on the master controller may be used to test piping networks and retardant sharing. Other standard tests, common with fire suppression systems of prior art, are also advised, such as verification of interconnections,

testing of the fire detection sensors, piping tests, operation of the extinguisher valves and sprinkler heads, etc.

The plurality of share control switches **140** on the master controller should be placed in AUTO mode when the system is ready for use. Thereafter, occasional maintenance refilling may be signaled by reservoir empty annunciators (for instance, due to small leaks), which should be attended to accordingly. The share control switches are useful for manual override of valves during system maintenance and testing. Note that, because of the breach valves, the system inhibits retardant sharing flow when there is an OPEN ("breach") condition on any of the continuity lines **110** associated to piping controlled by those sharing valves, even if sharing valves have been manually opened.

When any warning lamp illuminates on the panel of the master controller, it may indicate a sensor malfunction, or actual warning condition, and the operator at the master controller must ascertain the cause. For instance, when a share lamp **135** illuminates, and yet the associated fire lamp **345** and reservoir empty lamp **105** are not illuminated, the operator may suspect a malfunction, because sharing should only occur automatically when there is a fire detected, and when there is an empty reservoir, due to the configuration of the retardant share inhibitor **120**. (Normal operation in the case of a fire shows a fire lamp first illuminating, with possible subsequent indication of reservoir empty, and retardant sharing.)

If a discontinuity lamp illuminates on the panel of the master controller, it may be due to a failed continuity wire, or due to actual piping damage. Illumination of multiple discontinuity

lamps is likely an indication of a catastrophic damage to the building, due to explosion, earthquake, et cetera.

Thus the indicator lamps on the master controller provide the operator with a means to assess the extent of fire, damage, and fire extinguishing system operation, and possible malfunctioning subsystems.

Conclusion, Ramifications, and Scope

Accordingly, the reader will see that in the case of damage to the structure to be protected, such as that due to earthquakes, explosions, terrorist attacks, or other substantial damage, including failures to parts of the fire suppression system itself, the present invention holds great advantage over prior art. This is due to: autonomy of damage sensing, and compensation thereof; automatic retardant sharing between nodes; redundancies and spatial separation of sharing paths; selective sealing of sharing paths and isolation of reservoirs; a network of imbricated sensors; redundancy of sensors and controlling subsystems; and, where applicable, use of gravity to supply retardant from all available higher reservoirs.

The combination of control signals (manual or automatic), fire sensors, retardant level sensors, and damage sensors thus cause beneficial retardant flow between reservoirs to extinguish fires; or, isolation of reservoirs in a system-damaged scenario or when retardant sharing is not needed.

While the above description contains many specificities, these should not be construed as limitations on the scope of the

invention, but rather as an exemplification of one preferred embodiment thereof. Many other variations are possible. For example, the above description uses as an example a structure with a substantially vertical architecture. Substantially horizontal structures, such as cruise ships or warehouses, can also benefit by alternate embodiments of the invention. Also, water was used as an example of a fire retardant in the above description, but embodiments may use any suitable retardant, such as dry chemicals, foams, inert gases, powdered aerosols, halons, et cetera.

Accordingly, the scope of the invention should be determined not by the embodiment(s) illustrated, but by the appended claims and their legal equivalents.